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Comparison of Heritability and Variation for Milk Yield of Registered and Non-registered Holstein Cows

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ABSTRACT

First lactation milk records of AI Holstein cows in the northeastern United States were analyzed for among and within-sire variation separately by year of freshening, class of herd production, and registry status of registered or nonregistered with a model that included effects of herd-seasons, sires of sampling daughters, and sires of daughters of proven sires. Heritability from the paternal half-sib correlation among records of daughters of sampling sires was similar for registered and nonregistered cows. Differences in heritability in different years and class of herd production were similar to those found in previous analyses that ignored registry status. Residual variances were similar for records of registered and nonregistered cows. Differences in variances by year and class of herd production also were similar to those found in previous analyses. Residual variances of milk records increased with time and class of herd production and in the same year were distinctly larger in herds with higher production than in herds with lower production. Residual variances of logarithms of milk records changed little with time but in the same year were distinctly smaller in herds with higher production than in herds with lower production. Residual variances of square roots of milk records increased somewhat with time but in the same year were similar in different classes of herd production.

INTRODUCTION

Norman and Powell (15) and Everett (5) discussed the use of grade dairy cows and bulls for genetic improvement. Powell and Norman (17) also reported means for phenotypic records and estimated breeding values of registered and grade Holsteins. Among the numerous considerations are the basic questions of whether heritability and variation are different for records of registered and nonregistered cows. The answers to these questions are needed to develop methods of genetic evaluation and to design selection programs. Schneider and Van Vleck (19) have shown only slight differences in heritability estimates of milk yield for registered and nonregistered Holsteins based on daughter on dam regression. They also found large differences in heritability estimates associated with herd production, which is in agreement with many other studies (2, 4, 11, 14, 16, 23) for records of both registered and nonregistered cows. Variances are greater in higher production herds than lower production herds (1, 2, 4, 10, 11, 14, 20).

The purposes of this study were 1) to determine if variation due to sire effects is similar when measured in records of registered and nonregistered daughters and 2) to determine whether residual variation among records of registered and nonregistered cows is similar over all herds and by class of herd production.

MATERIALS AND METHODS

The data set previously described by Mirande and Van Vleck (14) consisted of first lactation, twice daily, 305-d mature equivalent milk records from the Northeast Dairy Records Processing Laboratory of 667,913 AI Holstein cows. Analyses were conducted separately for each year of freshening and also for each year of freshening and class of herd production. Each herd was assigned to one of four classes of production for each year based on the rolling herd average for milk yield as of May of that year. The rolling herd average is based on actual

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milk yield from all cows in the herd including first and later lactations. For each year the mean and standard deviation of the rolling herd average were calculated from the entire data set. The four classes were assigned corresponding to three dividing points: the mean minus one standard deviation, the mean, and the mean plus one standard deviation (13). Records for this study were further divided according to whether the cow was coded as registered or nonregistered Holstein. Other edits of the data are described by Mirande and Van Vleck (14) as are the definitions of proved and sampling bulls.

So that as many records as possible would contribute to the estimates of residual variances and only records of daughters made during their sire's sampling period would contribute to the estimate of the variance among sire effects (10, 12, 18), sire and residual components of variance were estimated by method 3 of Henderson (8) as described by Van Vleck (21) for the model:

$$\begin{pmatrix} y_1 \\ y_2 \end{pmatrix} = \begin{pmatrix} X_1 \\ X_2 \end{pmatrix} \begin{pmatrix} h \end{pmatrix} + \begin{pmatrix} Z_1 & 0 \\ 0 & Z_2 \end{pmatrix} \begin{pmatrix} s_1 \\ s_2 \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \end{pmatrix}$$

where y_1 and y_2 are the vectors of records of daughters of proved bulls and of daughters of sampling bulls; h is the vector of herd-year-season effects; s_1 and s_2 are the vectors of effects of proved and sampling bulls; e_1 and e_2 are corresponding vectors of random, uncorrelated residual effects; and X_1, X_2, Z_1, and Z_2 are matrices associating effects with records.

Residual variance is estimated as:

$$V_e = [y'y - R(h, s_1, s_2)] / [N - r(X, Z)]$$

where $R(h, s_1, s_2)$ is reduction in sum of squares due to fitting the complete model (herd-year-season and sires); N is the number of records; and r(X, Z) is the rank of the coefficient matrix for ordinary least squares equations for the full model.

Sire component of variance is estimated as:

$$V_S = [R(s_2|h, s_1) - r(Z_2'WZ_2)V_e] / tr(Z_2'WZ_2)$$

where $Z_2'WZ_2$ is the coefficient matrix after absorbing equations for h and s_1. Thus, only effects of sampling sires contribute to $R(s_2|h, s_1)$ (21).

Milk records as well as the natural logarithms and square roots of milk records were analyzed. Heritability estimates were four times the paternal half-sib correlations: $4V_S/(V_S + V_e)$. Plots of estimates of heritability and residual variances over time were smoothed by a median procedure. The median of five consecutive yearly estimates was taken to represent the middle of the 5 yr. Another smoothing procedure gave similar plots. In that procedure the smallest and largest estimates were thrown out of the set of five consecutive yearly estimates and the average of the three remaining estimates was taken to represent the middle of the 5 yr.

RESULTS AND DISCUSSION

Heritability

Figure 1 contains smoothed plots of heritability estimates for registered and nonregistered cows for milk records and logarithms of milk records. The plot for square roots of milk records is similar to those for milk records and logarithms of milk records and is not shown. Both plots are similar to those reported by Mirande and Van Vleck (14) in that estimates of heritability from sire components of

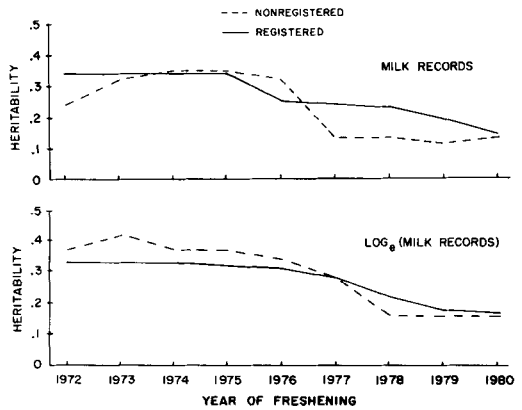

Figure 1. Heritability estimates from intraclass correlation after smoothing for milk records and for natural logarithms of milk records for registered and nonregistered Holsteins from analyses of first lactation records by year of freshening.

variance have decreased in recent years. Estimates of heritability from daughter-dam regression from the same data do not show a decrease in recent years (3, 19, 23). Figure 1 suggests little difference in heritability estimates from the paternal half-sib correlations for registered and nonregistered cows and from milk records, logarithms of milk records, and square roots of milk records.

The smoothed plots of heritability estimates for milk records over time by class of herd production are in Figure 2 for registered and nonregistered cows. Probably, because of the small number of sampling daughters per year (Table 1), the estimates fluctuate markedly even after smoothing. These estimates are in contrast to the estimates from daughter-dam regression that showed distinct increases in heritability estimates with increasing class of herd production for both registered and nonregistered cows (19), although in this study estimates from records in herds with low production were consistently smaller than from records in herds with higher production.

The estimates for low class of herd production for registered and nonregistered cows are based on the smallest number of sampling daughters of any grouping, especially for the later years for registered cows. This may explain the behavior of the heritability estimates, which are consistently negative for registered cows in herds with low production, whereas with the other three classes of production, estimates are similar. For registered cows, the plots by class of production are similar for milk records, logarithms, and square roots of milk records except that for logarithms of milk records the negative heritability estimates for the low class are even more extreme and estimates for the other three classes are even more variable than for milk records. Estimates for square roots of milk records are generally intermediate between those for milk records and logarithms.

Heritability estimates by class of herd production for nonregistered cows are more variable than for registered cows except that estimates for the low class of herd production (which had considerably more records than for registered cows in later years) were not negative when smoothed, although generally estimates for the low class of herd production were smaller than others. On the logarithmic scale estimates were somewhat more variable than for milk records. At the high class of herd production, smoothed estimates were negative for the last 3 yr. Again, the estimates for square roots of milk records were intermediate between those for milk records and logarithms. Estimates of heritability from records of nonregistered cows tend to show a greater decline in recent years than estimates from registered cows although the variation in estimates makes any conclusions tentative at best.

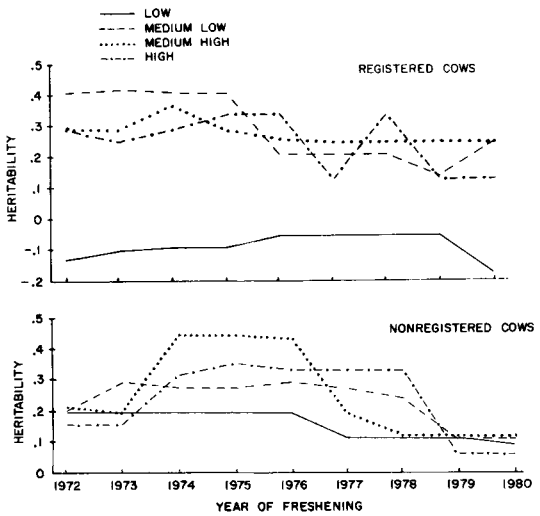

Figure 2. Heritability estimates after smoothing for first lactation milk records by year of freshening and class of rolling herd average (low to high); registered and nonregistered cows.

Residual Variances

Smoothed plots of residual variances are all relative to the largest variance in the figures, i.e., all other variances are divided by the largest variance. For example, after median smoothing, the largest variance in Figure 3, which compares residual variances of milk records for registered and nonregistered cows over time, is the variance for registered cows for 1980.

Figure 3 shows that the residual variances for milk records of registered cows were slightly larger than for nonregistered cows. The records of registered cows averaged from 180 to 320 kg more than records of nonregistered cows

TABLE 1. Numbers of records (N), records of sampling daughters (R), and sampling sires (S) in analyses by year of freshening and class of herd production.

	Class														
	Low			Medium low			Medium high			High			Overall		
Year	N	R	S	N	R	S	N	R	S	N	R	S	N	R	S
	Registered														
1970	1894	358	132	5581	1060	219	6630	1138	205	2978	505	138	16,883	3061	278
1971	1934	399	145	5311	1063	203	6372	1253	209	3063	527	152	16,690	3242	271
1972	1924	430	127	5009	1005	191	6285	1250	224	3021	552	146	16,239	3237	271
1973	1978	327	120	4857	786	172	6345	992	195	2959	437	146	16,139	2542	262
1974	2161	372	122	5092	733	179	6914	1052	196	3449	459	153	17,616	2615	258
1975	1951	294	114	5477	809	320	7537	1100	234	3461	470	166	18,426	2673	301
1976	2185	399	135	6186	1010	232	7572	1162	246	3478	456	176	19,421	3027	327
1977	2310	461	167	6411	1133	275	8050	1296	275	3532	531	177	20,303	3421	374
1978	2116	392	155	6136	1123	291	8001	1238	286	3928	555	191	20,181	3308	411
1979	2295	425	162	6956	1016	269	9746	1351	317	4276	465	173	23,273	3257	426
1980	2648	422	171	8095	1075	289	9994	1148	285	4938	508	169	25,675	3153	412
1981	2942	346	145	8749	1083	284	11,268	1114	287	5503	470	169	28,462	3013	428
1982	1610	220	97	4439	529	177	6533	755	216	3235	317	123	15,817	1821	312
	Nonregistered														
1970	2359	229	88	4951	415	138	4285	294	95	1516	115	65	13,111	1053	183
1971	2450	253	97	5272	514	130	4794	401	114	1528	131	61	14,044	1299	184
1972	2511	278	105	4932	506	126	4936	474	117	1918	207	82	14,297	1465	186
1973	2844	214	92	4835	446	112	5058	449	130	1806	154	76	14,543	1263	186
1974	3035	236	84	5723	547	132	5225	473	117	2253	181	80	16,236	1437	190
1975	3342	336	120	6420	681	176	5867	611	159	2398	267	109	18,027	1895	247
1976	3770	394	134	6948	745	183	6682	656	172	2327	221	101	19,727	2016	268
1977	4022	527	156	7163	785	195	6868	679	202	2673	246	116	20,726	2237	305
1978	3860	437	152	8315	979	246	7559	746	199	2604	259	116	22,338	2421	344
1979	4846	572	195	10,011	1010	215	8886	930	222	3580	339	140	27,323	2851	352
1980	5203	547	186	10,958	1083	214	10,186	981	235	3968	357	149	30,315	2968	359
1981	6314	717	222	13,296	1462	280	11,855	1208	260	4976	421	144	36,441	3808	399
1982	4048	489	170	7590	958	216	7598	878	195	2850	269	108	22,086	2594	311

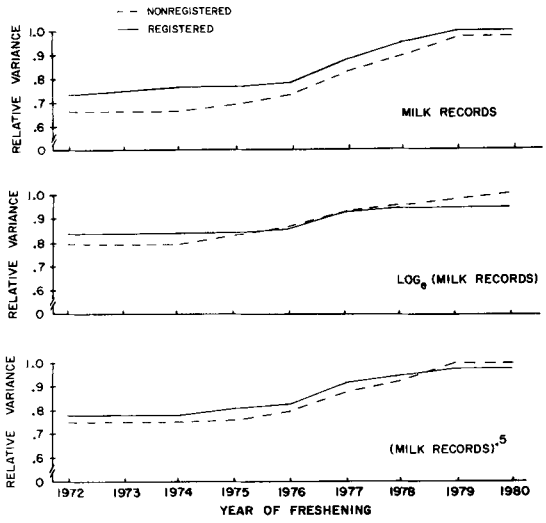

Figure 3. Estimates of residual variances after smoothing for milk records, natural logarithms of milk records, and square roots of milk records for registered and nonregistered Holsteins from analyses of first lactation records by year of freshening. Estimates are relative to the largest variance for that scale: milk records of registered cows, 1,780,000 kg^2; natural logarithms of milk records of nonregistered cows, .0352, square roots of milk records of nonregistered cows, 60 kg.

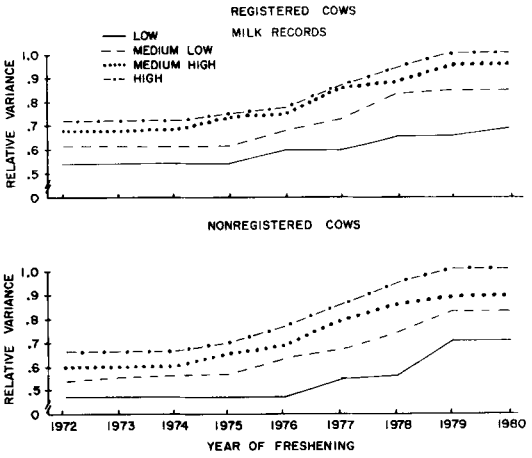

Figure 4. Smoothed estimates of residual variances by year of freshening and class of herd production for milk records of registered Holstein cows and nonregistered Holstein cows. Estimates are relative to the largest variance for each registry status: registered, high herd production; 1,965,000 kg^2, and nonregistered, high herd production; 2,057,000 kg^2.

so that some of the difference in variance may be due to the increase in variance with increased herd production. On the logarithmic scale (Figure 3), the variances are more similar for registered and nonregistered cows than estimates for nontransformed records except that in more recent years (actual, not smoothed, variances for 1978 through 1982) the variances of records of nonregistered cows are larger than for registered cows. The pattern for square roots of records is intermediate, as shown in Figure 3. Differences in variances between records of registered and nonregistered cows shown in Figure 3 may be due to the somewhat higher herd production of registered cows on the average.

Smoothed plots of residual variances of milk records are in Figure 4 for records separated into the four classes of herd production. Variances for records of both registered and nonregistered cows show the pattern reported by Mirande and Van Vleck (14). Variances are larger for records made in herds with higher production than in herds with lower production. The relative increase in variance with time appears somewhat greater for nonregistered cows than the increase for registered cows even though the production averages for registered and nonregistered cows in herds in same production class were similar.

Smoothed plots of residual variances of logarithms of milk records are in Figure 5 by class of herd production. As reported earlier for this data set (14), the association between herd production and residual variance is reversed for logarithms as compared to untransformed records. Variances are larger in herds with lower than in herds with higher production. Variances among records for nonregistered cows increased slightly more with time than for registered cows. In fact, variances in the log scale in the last few years of the data were larger for records of nonregistered than for registered cows at all classes of herd production.

The smoothed plots for residual variances for square roots of milk records are shown in Figure 6. The patterns are similar for records of both registered and nonregistered cows except that the variance for the low herd production class is not as similar to variances for the other production classes for nonregistered cows as for

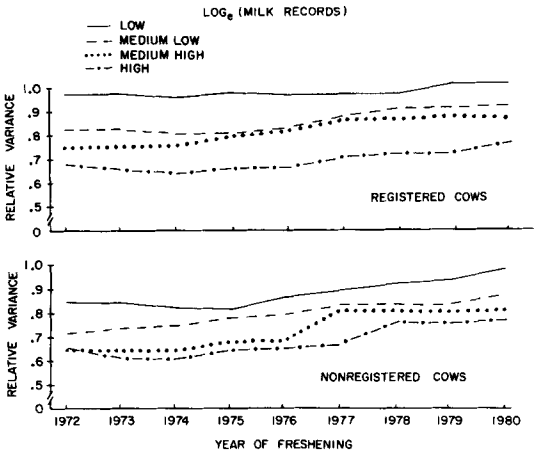

Figure 5. Smoothed estimates of residual variances by year of freshening and class of herd production for natural logarithms of milk records of registered Holstein cows and nonregistered Holstein cows. Estimates are relative to the largest variance for each registry status: registered, low herd production; .0383, and nonregistered, low herd production; .0405.

registered cows. The increase in variance with time is slightly more for records of nonregistered cows than for registered cows when plotted by class of herd production that was assigned separately for each year.

Comparisons of Figures 4, 5, and 6 show that within year, variances are more nearly the same for all classes of herd production for square roots than for milk records or logarithms. Within class of herd production quartiles, the change in variance with time is smallest for logarithms of records of registered cows. For all three measurement scales, the change over time is less for records of registered than for nonregistered cows. Within class of herd production quartiles change in variance is least for logarithms of milk records and greatest for milk records with square roots of milk records intermediate.

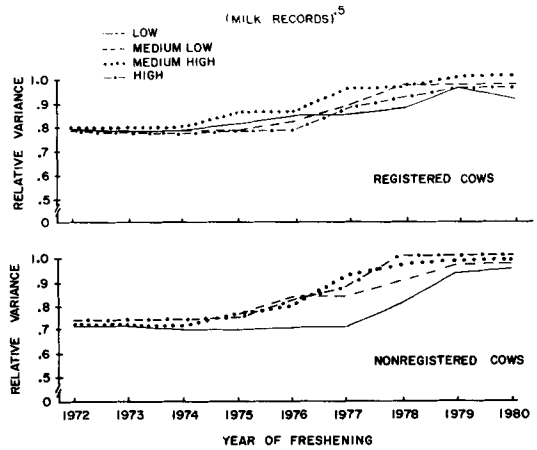

Figure 6. Smoothed estimates of residual variances by year of freshening and class of herd production for square roots of milk records of registered Holstein cows and nonregistered Holstein cows. Estimates are relative to the largest variance for each registry status: registered, medium herd production; 59.9 kg, and nonregistered, high herd production; 61.2 kg.

CONCLUSIONS

Paternal half-sib correlations cannot be said to be different for records of registered and nonregistered cows and for scale of measurement: milk records, logarithms of milk records, and square roots of milk records. Reasons for the decrease in paternal half-sib correlations in later years are not known. Daughter on dam regression coefficients do not show any decrease in later years (3, 19, 23). As suggested by Mirande and Van Vleck (14), selection for sires and dams of sampling bulls can account for only part of the approximate halving of the fraction of variance due to sire effects (18). The contrast between heritability estimates from daughter on dam regression and from paternal half-sib correlations is startling. In earlier years, the estimates are quite similar overall but not in later years. Estimates of heritability are distinctly different across classes of herd production from daughter on dam regression but not from paternal half-sib correlation. What is most puzzling are the extremely small paternal half-sib correlations in recent years overall production classes and relatively small paternal half-sib correlations from herds with high production for both registered and nonregistered cows. Preferential treatment and misidentification are two possible sources of biases in paternal half-sib correlation. Differential preferential treatment would seem likely to inflate estimates and misidentification to decrease estimates.

Residual variances of registered and nonregistered cows follow the same patterns. The

patterns are different for milk records, logarithms of milk records, and square roots of milk records. The patterns are similar to those described earlier by Mirande and Van Vleck (14). The influence of different residual variances from herd to herd on selection and evaluation has been discussed (1, 6, 7, 9, 11, 22).

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